

Formal Safety Certification of Aerospace Software

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In principle, formal methods offer many advantages for aerospace software development: they can help to achieve ultra-high reliability, and they can be used to provide evidence of the reliability claims which can then be subjected to external scrutiny. However, despite years of research and many advances in the underlying formalisms of specification, semantics, and logic, formal methods are not much used in practice. In our opinion this is related to three major shortcomings. First, the application of formal methods is still expensive because they are labor- and knowledge-intensive. Second, they are difficult to scale up to complex systems because they are based on deep mathematical insights about the behavior of the systems (i.e., they rely on the “heroic proof”). Third, the proofs can be difficult to interpret, and typically stand in isolation from the original code.

In this paper, we describe a tool for formally demonstrating safety-relevant aspects of aerospace software, which largely circumvents these problems. We focus on safety properties because it has been observed¹ that safety violations such as out-of-bounds memory accesses or use of uninitialized variables constitute the majority of the errors found in the aerospace domain. In our approach, safety means that the program will not violate a set of rules that can range from the simple memory access rules to high-level flight rules. These different safety properties are formalized as different *safety policies* in Hoare logic, which are then used by a verification condition generator along with the code and logical annotations in order to derive formal safety conditions; these are then proven using an automated theorem prover. Our certification system is currently integrated into a model-based code generation toolset that generates the annotations together with the code. However, this *automated formal certification* technology is not exclusively constrained to our code generator and could, in principle, also be integrated with other code generators such as RealTime Workshop or even applied to legacy code.

Our approach circumvents the historical problems with formal methods by increasing the degree of automation on all levels. The restriction to safety policies (as opposed to arbitrary functional behavior) results in simpler proof problems that can generally be solved by fully automatic theorem provers.² An automated linking mechanism between the safety conditions and the code provides some of the traceability mandated by process standards such as DO-178B.³ An automated explanation mechanism uses semantic markup added by the verification condition generator to produce natural-language explanations of the safety conditions and thus supports their interpretation in relation to the code. Figure 1 shows an automatically generated *certification browser* that lets users inspect the (generated) code along with the safety conditions (including textual explanations), and uses hyperlinks to automate tracing between the two levels. Here, the explanations reflect the logical structure of the safety obligation but the mechanism can in principle be customized using different sets of domain concepts. The interface also provides some limited control over the certification process itself.

Our long-term goal is a seamless integration of certification, code generation, and manual coding that results in a “certified pipeline” in which specifications are automatically transformed into executable code, together with the supporting artifacts necessary for achieving and demonstrating the high levels of assurance needed in the aerospace domain.

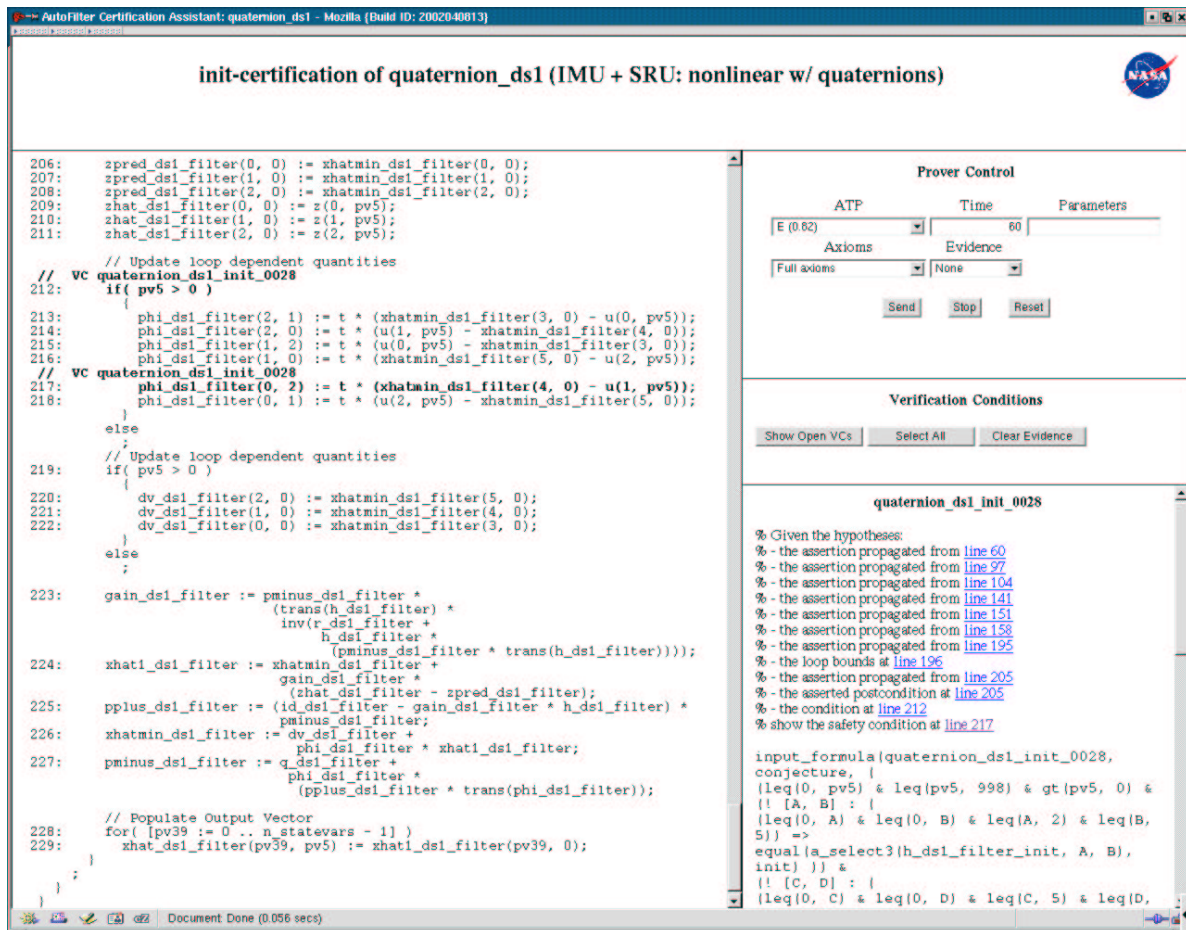


Figure 1. Certification browser

References

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- ³RTCA Special Committee 167, "Software Considerations in Airborne Systems and Equipment Certification," Tech. rep., RTCA, Inc., Dec. 1992.